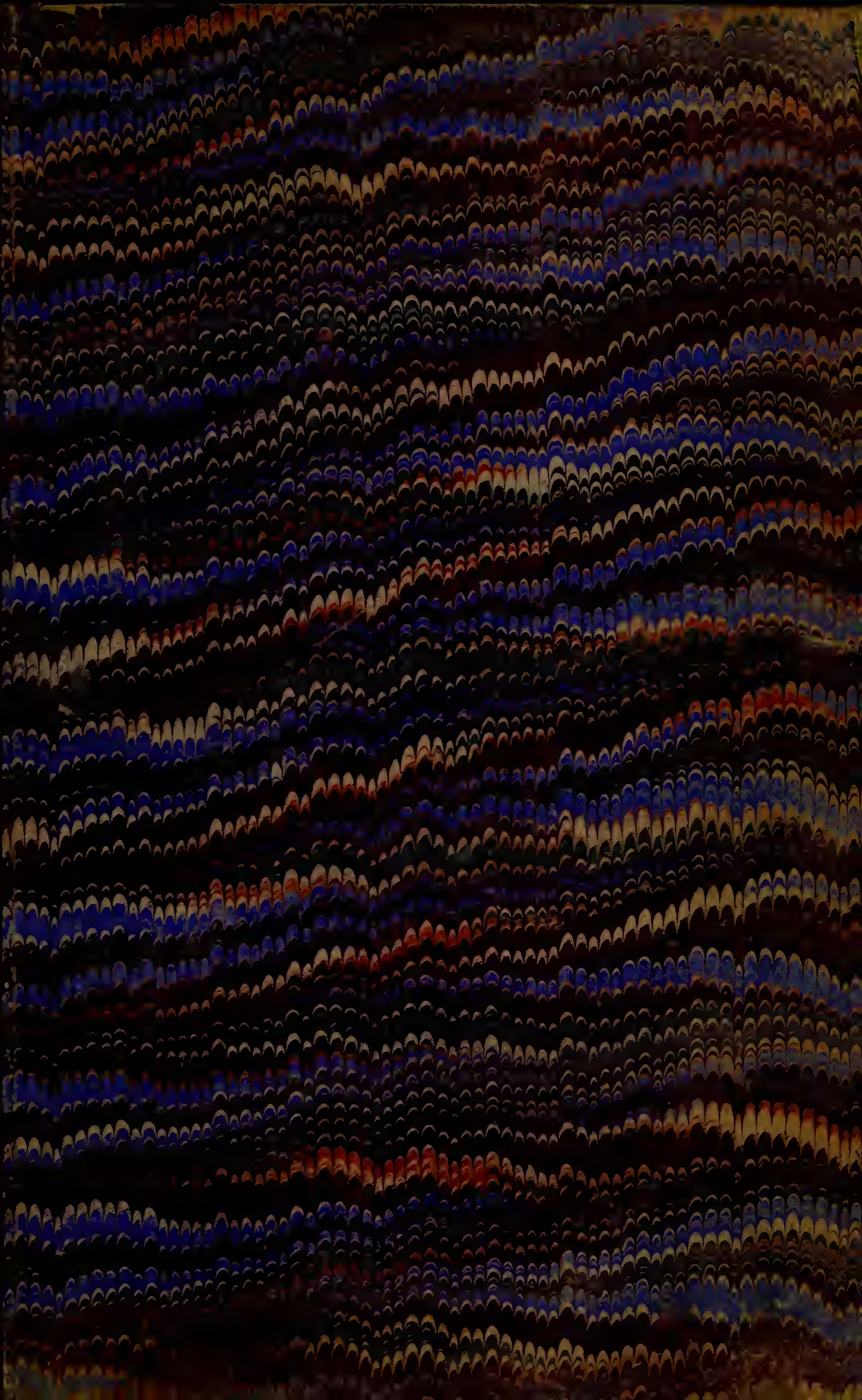

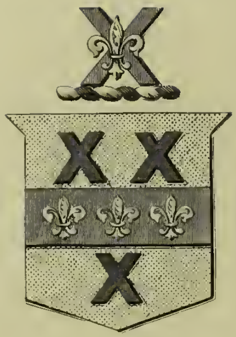

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A NOTE BOOK

FOR THE

ELEMENTS OF THE COMPARATIVE ANATOMY OF VERTEBRATES

BY

PROFESSOR J. STANLEY GARDINER

AND

MR C. FORSTER COOPER

CAMBRIDGE
PRINTED AT THE UNIVERSITY PRESS
1911

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TABLE OF CONTENTS.

PAGE
INTRODUCTION v
CLASSIFICATION OF THE VERTEBRATA ix
SCHEME GIVING EQUIVALENCE OF GROUPS OF MAMMALIA . . x
CLASSIFICATION OF MAMMALIA . xi
ACRANIA (Amphioxus) 1–3
CRANIATA (General Anatomy) 4–23
Cyclostomata 4–5
Pisces 6–14
Tails of Pisces 6
Skate 7–8
Chlamydoselachus and Chimæra 9
Whiting 10–11
Sturgeon 12
Amia and Polypterus 13
Protopterus and Ceratodus 14

PAGE
Amphibia 15–16
Reptilia 17–18
Aves (Pigeon) 19–21
Mammalia (Rabbit, etc.) 22–23
GILLS 24
VASCULAR SYSTEM 25–31
URINOGENITAL ORGANS 32–38
NERVOUS SYSTEM 39–44
EXOSKELETON 45–48
VERTEBRAL COLUMN 49–51
STERNUM, PECTORAL GIRDLE AND LIMB 52–57
PELVIC GIRDLE AND LIMB 58–63
SKULL 64–73
TEETH 74–75
SKULLS AND TEETH OF MAMMALIA 76–84

INTRODUCTION.

THE arrangement of this Notebook is as follows:—

The external features of each form, as noted under the various headings, are to be drawn first. Next the general anatomy of the viscera as seen on opening the animal, but with a minimum of cutting, the idea being to give a general view of the relations of the organs to one another in situ. Drawings should be of a semi-diagrammatic nature. It is a good plan to make preliminary drawings on loose paper while the examination of the specimen is in progress and then, when the topographical anatomy is mastered, to arrange the various organs to show as much as possible: i.e. the intestine may be unravelled and turned to one side, the lobes of the liver turned up out of the way and so on. When one organ covers another the overlying one may be dotted in in outline, or in the case of paired bilaterally symmetrical ones the organs may be left out on one side. In this way it is possible to show a great deal of anatomical detail in one drawing. A drawing of the frog is here given to illustrate these ideas (see page vii).

All the drawings in the first instance should be sketched lightly in pencil to admit of corrections. These outlines may then be re-drawn more permanently in ink or pencil. Shading as a rule is inadvisable; colours are valuable but should be used with judgment. Some system should be adhered to throughout, whereby one colour is kept for each organ, e.g. red for arteries, blue for veins, brown for renal organs, green for the generative system, and so on.

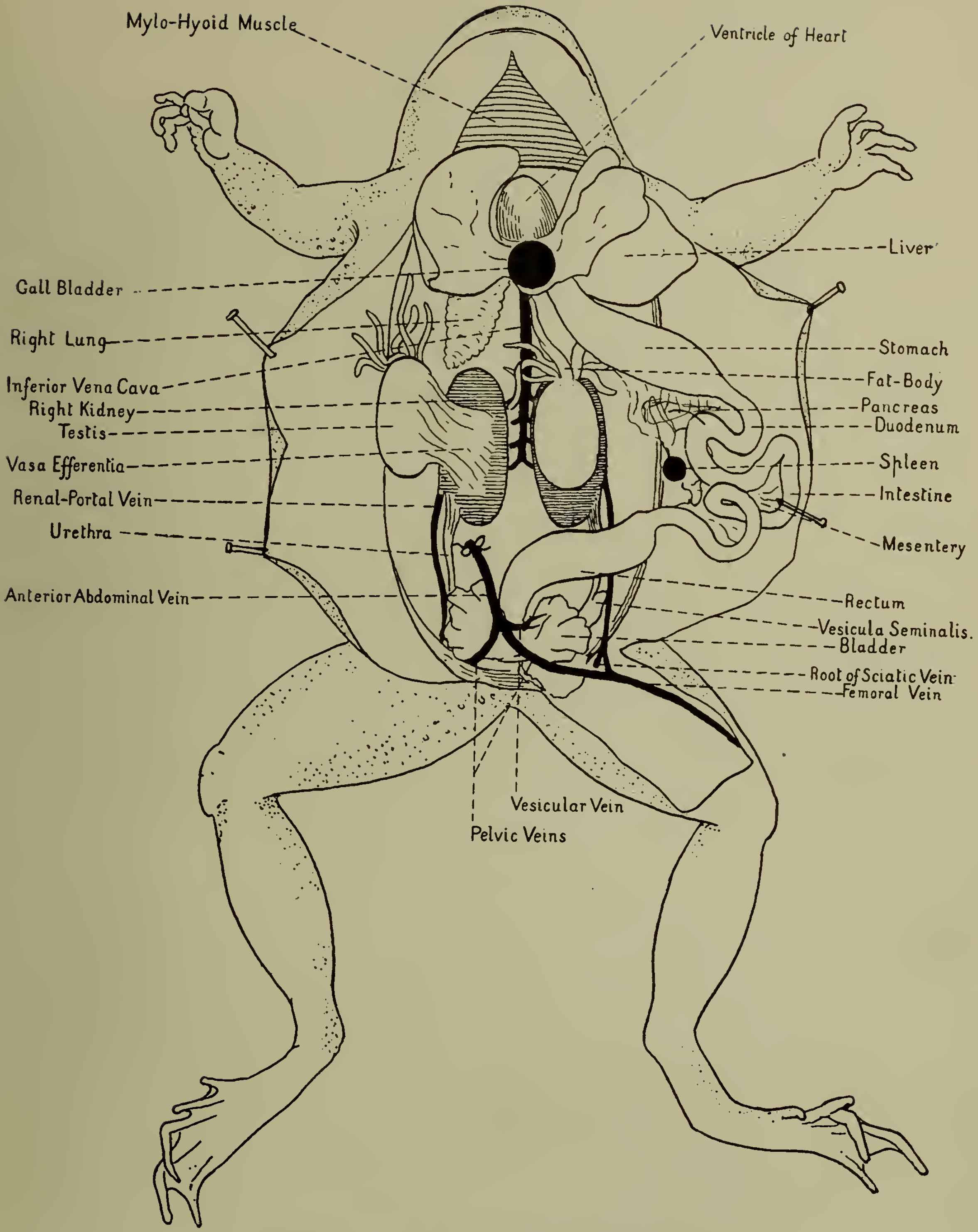
It will be noticed that the Notebook is so arranged that the various organs are placed together, so that their anatomy in the different groups of vertebrates may be readily compared. Thus the circulatory systems of the Skate, Whiting, Frog, Lizard, Pigeon and Rabbit all follow one another: and the other organs are arranged in the same way to facilitate comparison. It follows that in the Practical Work in the Laboratory it will be necessary, after the external characters and topographical anatomy have been drawn, to turn to different parts of the Notebook for the various other organs. The pages in the Notebook are announced in the Laboratory at the beginning of the Practical Work.

The left-hand pages in the Notebook are left blank. They may be used for additional drawings of and notes on demonstration specimens, etc., but places will be found in the Notebook for most of the latter. Another method of using them is for lecture notes. These may be taken down roughly in pencil, and later transcribed on to the appropriate pages opposite the group of animals or the particular organ to which they refer. Obviously diagrams or descriptions intended largely as aids to dissection need not be copied. If this method is adopted this Notebook may be made into a Textbook of the Comparative Anatomy of Vertebrates more valuable to its owner than any printed book, both for examination purposes and for subsequent reference.

Full use should be made of the series of skulls in the Laboratory, and the demonstration specimens placed out from time to time should be examined carefully. Numerous further anatomical and osteological specimens are to be found in the Museum. It is advisable that the Museum should be visited at various times and that students should make themselves fully acquainted with the variety of form and structure found in the different Groups of Vertebrates.

We desire to express our great indebtedness to Professor Adam Sedgwick, who for 27 years directed our Laboratory, and under whom we worked from our student days. We would also express our obligations to Dr H. Gadow, whose lectures on the Comparative Anatomy of Vertebrates were most illuminating. We have to thank Mr W. O. Redman King and Mr A. B. Appleton for working through many of the dissections. We also have received much valuable criticism from Mr H. H. Brindley.

ZOOLOGICAL LABORATORY,
CAMBRIDGE.
January, 1911.



GENERAL ANATOMY OF FROG.

CLASSIFICATION OF THE VERTEBRATA.

- I. ACRANIA (Amphioxus).
- II. CRANIATA.
  - A. Cyclostomata (Lamprey, Myxine).
  - B. Gnathostomata.
    - *a.* Pisces.
      - I. Elasmobranchii.
        - 1. Selachii (Sharks and Rays).
        - 2. Holocephali (Chimæra).
      - II. Teleostomi.
        - 1. Actinopterygii.
          - i. Chondrostei (Sturgeon).
          - ii. Holostei (Garpike).
          - iii. Teleostei (Bony fishes).
        - 2. Crossopterygii (Polypterus).
      - III. Dipnoi (Ceratodus, Protopterus, Lepidosiren).
    - *b.* Amphibia.
      - I. Urodela (Salamander).
      - II. Anura (Frogs).
      - III. Gymnophiona (Cœcilians).
      - IV. *Stegocephali.*
    - *c.* Reptilia.
      - I. Rhynchocephalia (Sphenodon).
      - II.
        - Lacertilia (Lizards).
        - Ophidia (Snakes).
      - III. Crocodilia (Crocodiles).
      - IV. Chelonia (Tortoises and Turtles).
      - V. *Dinosauria.*
      - VI. *Plesiosauria.*
      - VII. *Ichthyosauria.*
      - VIII. *Pterodactyla.*
      - IX. *Anomodontia.*
    - *d.* Aves.
      - I. *Archæornithes* (Archæopteryx).
      - II. Neornithes.
        - 1. Ratitæ (Ostrich, Emu, Rhea, Cassowary).
        - 2. Carinatæ (Most birds).
    - *e.* Mammalia.
      - I. Prototheria (Ornithorhynchus, Echidna).
      - II. Metatheria (Marsupials).
      - III. Eutheria (Placental Mammals).

(The most important extinct orders are shown in italics.)

SCHEME GIVING EQUIVALENCE OF GROUPS OF MAMMALIA.

Prototheria			Monotremata	
Metatheria			Polyprotodontia Diprotodontia	
Eutheria	Unguiculata	*Pantotheria*		
		Insectivora		
		Dermoptera		
		Cheiroptera		
		Carnivora	*Creodonta* Fissipedia Pinnipedia	
		Cetacea	*Zeuglodontia* Odontoceti Mystacoceti	
		Rodentia		
		Edentata	Xenarthra Nomarthra Tubulidentata	
	Primates		Lemuroidea Anthropoidea	
	Ungulata	*Condylarthra*		Holarctic
		Amblypoda		
		Artiodactyla		
		Perissodactyla		
		Proboscidea		African
		Hyracoidea		
		Sirenia		
		Toxodontia		S. American
		Typotheria		
		Litopterna		

CLASSIFICATION OF MAMMALIA.

A. Egg-laying Mammals, without nipples.

- I PROTOTHERIA.
  - (i) **MONOTREMATA.** *Ornithorhynchus. Echidna.*
    Australia, Tasmania, New Guinea, no fossil history.

B. Mammals producing their young alive; with nipples.

- II. METATHERIA or MARSUPIALIA.
  - (i) **POLYPROTODONTIA.** Opossums, Dasyures, Thylacines, Bandicoots, Pouched Mole etc.
    Australia and America (Opossums).
  - (ii) **DIPROTODONTIA.** Phalangers, Sloth bear (*Phascolarctus*), Rat kangaroos, Kangaroos, Wallabies etc.
    All Australian except the S. American rat-like *Cænolestes* and *Chironectes.*

  Fossil forms abundant and widely spread over Europe in early tertiary times. Now restricted to Australian region, South America and one form *Didelphys* also in North America.

- III. EUTHERIA or PLACENTALIA. No pouches, placenta always present.
  - (A) **UNGUICULATA.**

    Clawed mammals; variously adapted to terrestrial, fossorial, arboreal, cursorial, aquatic and volant life: includes the most primitive living forms as well as highly specialised modern forms.

    - (i) *Pantotheria. Primitive insectivore-like mammals of the mesozoic period; possibly still metatherian.*
    - (ii) Insectivora. Fossil and modern insectivores, e.g. Shrews, Moles, Tenrecs, Hedgehogs: contain the most primitive of living Eutheria.
    - (iii) Dermoptera. The "Flying Lemur" of Malaysia (*Galeopithecus*).
    - (iv) Cheiroptera. Bats, Fruitbats, Vampires etc.
    - (v) Carnivora.
      - (α) *Creodonta. Primitive carnivores becoming extinct in the Oligocene.*
      - (β) **Fissipedia.** True carnivores, Cats, Dogs, Bears, Hyænas, Racoons, Otters, Weasels etc.
      - (γ) **Pinnipedia.** Seals, Walruses etc.
    - (vi) Cetacea.
      - (α) *Zeuglodontia.* Primitive whales.
      - (β) **Odontoceti.** Toothed whales.
      - (γ) **Mystacoceti.** Whalebone whales.
    - (vii) Rodentia. Rats, Mice, Squirrels, Beavers, Porcupines etc.
    - (viii) Edentata.
      - (α) **Xenarthra.** True South American edentates, without enamel on teeth. Sloths, Armadillos, Anteaters etc.
      - (β) **Pholidota.** "Scaly Anteaters" of India and Africa.
      - (γ) **Tubulidentata.** "Aardvarks" of South Africa.

(B) **PRIMATES.**

Primarily adapted to arboreal life. Digits terminating in nails or more rarely claws. The more primitive forms are closely allied to the primitive Unguiculate Insectivora.

- i. LEMUROIDEA. Lemurs, Aye-Aye etc.
- ii. ANTHROPOIDEA. Monkeys and Apes, Marmosets, Baboons, Man.

(C) **UNGULATA.**

Hoofed mammals. Herbivorous, primarily cursorial, secondarily aquatic and arboreal; originally derived from the Unguiculata.

(i) Arctogæan hoofed mammals of (A) N. America, Asia and Europe.
(B) Africa.

- (A) Of Holarctic origin.
  - (α) *CONDYLARTHRA. Primitive light-limbed animals, surviving only to the middle Eocene.*
  - (β) *AMBLYPODA. Primitive heavy-limbed animals, surviving to upper Eocene.*
  - (γ) ARTIODACTYLA. Even-toed hoofed animals—Pigs, Hippopotami, Cattle, Deer, Giraffes, Antelopes, Sheep, Goats, Camels, Chevrotains and many extinct forms.
  - (δ) PERISSODACTYLA. Odd-toed hoofed animals. Tapirs, Horses and Zebras, Rhinoceros, and extinct forms.
- (B) Of African origin.
  - (ε) PROBOSCIDEA. *Palæomastodon*, *Mastodons* and Elephants.
  - (ζ) SIRENIA. Manatees and Dugongs.
  - (θ) HYRACOIDEA. Conies.

(ii) *Neogæan hoofed animals—special orders of ungulates now extinct evolved in South America.*

- (κ) *TOXODONTIA.*
- (λ) *TYPOTHERIA.*
- (μ) *LITOPTERNA.*

1. Left side view of unmacerated specimen: *myotomes*; *dorsal fin*; *caudal fin*; *anal fin*; *generative organs*; *mouth*; *oral cirri*; *anus*; *atrial pore.*

2. Ventral view of same: *ventral groove*; *metapleural folds*; other names as above.

3. A specimen macerated in 20 per cent. nitric acid for 24 hrs. Remove the wall of the atrial cavity on the right side: *mouth*; *oral cirri*; *pharynx*; *gill slits*; *liver*, on right side only; *intestine*; *anus*; *notochord*; *spinal cord*; *fin rays*; *generative organs.*

4. Remove and stain the hind end of the pharynx, slitting it open dorsally and flattening out the two sides: *skeletal bars*, alternately forked and unforked ventrally; *transverse connectives*; *developing gill slits.*

5. Remove the spinal cord by shaking the specimen in a test tube in water, stain and mount: *eye spot*; *dorsal nerves* (sensory), arising in pairs in front, gradually becoming alternate on the two sides; *ventral nerves* (motor).

6. Transverse section through pharyngeal region: *myotomes*; *notochord*; *sheath of same* prolonged between the myotomes and round the *spinal cord*; *pharynx*; *gill-slits*; *endostyle*; *dorsal groove of pharynx*; *dorsal aortae*; *atrial cavity*; *cœlome*; *generative organs*; *endostylar vessel*; *liver*; *ventral groove*; *metapleural folds*; *dorsal fin*.

7. Transverse section through intestine behind atrial pore: *intestine*; *dorsal aorta*; *sub-intestinal vessels*; *anal fin*; *myotomes*; *spinal cord*; *notochord*.

8. Examine the demonstration specimens. Make notes and drawings where necessary.

1. Side view of Lamprey (*Petromyzon*): *suctorial mouth*; *nasal aperture*; *eye*; *gill-slits*; *myotomes*; *dorsal fin*; *caudal fin*; *anus*; *urinogenital papilla.*

2. Side view of Hag-fish (*Myxine*): *mouth*; *tactile processes*; *nasal aperture*; *position of eye*; *opening of branchial duct*; *anus*; *fins.*

3. Examine the demonstration specimens of the group. Make notes and drawings where necessary.

4. The form and structure of the tail in fishes: observe the *spinal cord*, *vertebral column* and *caudal fin*.

(*a*) *Protocercal* type (Cyclostomata); also called *diphycercal.*

(*b*) *Heterocercal* type (Sturgeon and Elasmobranchii).

(*c*) *Homocercal* type. (i) *Amia.*
(ii) Most Teleostei.

(*d*) *Secondarily protocercal* type (*Polypterus* and Cod), derived from the homocercal; also called *gephyrocercal.*

5. Dorsal view of Skate: *eyes*; *spiracles* with *pseudobranchs*; *pectoral fins*; *dorsal fins*; *lateral line.*

Ventral view of same: *mouth*; *oro-nasal grooves*; 5 *gill-slits*; large and small *placoid scales*; *cloaca*, showing *urinogenital papilla* and *opening of rectum*; *abdominal pores*; *pectoral* and *pelvic fins*; *claspers in male.*

6. View of contents of the body cavity of the Skate: make a median incision through the abdominal wall and complete flaps by two transverse incisions, viz. behind the last gill-slits and along the anterior border of the right pelvic fin; cut through the pelvic girdle and remove the left pelvic fin: *trilobed liver*; *gall bladder*; *bile duct*; *cardiac stomach*; *pyloric stomach*; *spleen*; *intestine* with *spiral valve*; *pancreas*; *pancreatic duct*; *rectum*; *rectal gland*; *cœliac artery*; *portal vein*; *testis* or *ovary*; *internal opening of oviducts in* ♀ or *vestige of same in* ♂; *oviduct* or *vas deferens*; *abdominal pores.*

7. Side view of head of *Chlamydoselachus*: *terminal mouth*; *six gill-slits*; *rudimentary operculum.* Examine the teeth and note external features of the whole animal.

8. Side view of *Chimæra*: *mouth*; *nasal aperture* and *oro-nasal groove*; *operculum covering gills*; *endolymphatic opening*; *mucous glands on head and along lateral line*; *cloaca*; *pectoral*, *pelvic*, *dorsal*, *anal* and *caudal fins*; in male *clasper* on head, *anterior pair of claspers* in front of pelvic fin and *pelvic claspers* as in Skate. Examine the teeth.

9. Side view of Whiting: *terminal mouth with teeth*; *nasal aperture* divided into two by a fold of skin; *eye*; *operculum*; *branchiostegal membrane*; *pectoral* and *pelvic fins*; *dorsal, anal* and *caudal fins*; *homocercal tail*; *anus*; *urinogenital aperture*; *cycloid scales*; *lateral line*; *myotomes.*

Examine the demonstration specimens of the Teleostei to see the variety of form in the group.

10. View of contents of the body cavity of the Whiting: make a flap of right wall of abdominal cavity, by an incision passing anterior to the anus, and turn this flap back: *œsophagus*; *dorsal* and *ventral mesenteries*; *trilobed liver*; *gall bladder*; *bile duct*; *stomach*; *pyloric appendages*; *intestine*; *spleen*; *rectum*; *air bladder*, united to œsophagus by a band of strong tissue; *cœliac artery*; *portal vein*; *hepatic veins*; *testis* or *ovary*; *vas deferens* or *oviduct*; *ureter*. Pass a seeker from the exterior, first into the ureter, then into the generative duct.

Examine the kidneys, by removing the dorsal wall of the air bladder. Observe *vascular plexus* of air bladder and trace ureter into kidneys.

Drawing of the *gut* and *air bladder* of the Sprat to show their relationship to one another.

11. Side view of Sturgeon: *snout*; *tactile processes*; *suctorial mouth*; *double nasal aperture*; *spiracle*; *operculum covering gills*; *fins*; *cloaca*; *heterocercal tail*; *bony scutes* covering head and operculum and forming five rows on the body.

12. Side view of *Amia*: *mouth*; *nasal apertures*; *single jugal plate*; *bony plates on head and operculum*; *ganoid scales*; *lateral line*; *continuous dorsal fin*; *homocercal tail.*

13. Side view of *Polypterus*: *mouth*; *tactile processes*; *nasal apertures*; *spiracle* covered by *valve*; *pair of jugal plates*; *operculum*; *ganoid scales*; *lateral line*; *cloaca*; *pectoral* and *pelvic fins* with fleshy lobes at bases; *dorsal fin* broken up and supported by spines; *secondarily protocercal tail*; *anal fin.*

14. Side view of *Protopterus*: *mouth*; *anterior nares*; *paired fins* filamentous; *external gills*; *branchial aperture*; *small cycloid scales*; *lateral line*; *secondarily symmetrical tail.*

15. Side view of *Ceratodus*: organs as above; note the *fleshy paired fins*, no external gills and *large cycloid scales.*

Examine demonstration specimens of *Lepidosiren.*

16. Side view of *Hypogeophis*: notice vermiform shape, absence of limbs, terminal anus and annulated body.

17. Side view of *Necturus*: notice the 3 pairs of external gills and the flattened swimming tail. Examine the demonstration specimen for the gill-slits.

18. Side view of Newt (*Molge cristata*): notice the crest to the body in the male during the breeding season.

19. Examine the demonstration specimens illustrating the classification and natural history of the order. Make notes and drawings, where necessary.

20. Examine the demonstration specimens illustrating the classification and natural history of the order. Make notes and drawings where necessary.

21. Side view of Pigeon with wing extended: *bastard wing*; *primaries*; *secondaries*; *wing coverts*; *mouth*; *anterior nares*; *ear*; *nictitating membrane of eye*; *rectrices of tail*; *oil gland*; *cloaca*; *hind limbs.*

22. *Dissection.* Reflect the skin carefully from the thorax and neck. Note on the under part of the neck the large crop. Separate the large superficial muscle of the breast (pectoralis major) of one side from the keel of the sternum and from the entire length of the clavicle. Reflect the muscle forwards, taking care not to injure the axillary blood-vessels; observe close to these vessels the axillary air-sacs. Note the deeper muscle of the breast (pectoralis minor) still attached. Reflect it forwards by cutting through its origin, and make out the insertion of both pectoral muscles and their mode of action. Dissect away the pectoral muscles of the other side in the same manner; open the abdomen and raise the hind end of the sternum, cutting through attachment of sternum to ribs and coracoid on both sides, and remove the sternum.

Diagram showing relations of air-sacs and lungs: *trachea*; *syrinx*; *bronchi*; *lungs*; *air-sacs* as follows, median *interclavicular* and paired *axillary*, *anterior thoracic*, *posterior thoracic* and *abdominal.*

23. General anatomy of the Pigeon after removal of sternum, viscera being pulled out to one side: *œsophagus*; *crop*; *stomach* (*gizzard*); *duodenum*; *liver* and *bile ducts* (2); *pancreas* and *ducts* (3); *small intestine*; *rectum*; *rectal cæca*; *cloaca*; *spleen*; *lungs*; *heart*; *portal vein*; *coccygeo-mesenteric vein*.

24. General anatomy of the Rabbit; make a median ventral incision through the skin of the trunk and neck and reflect the skin well outwards; open the abdomen in the middle line and cut round so as to remove the sternum and ventral halves of the ribs; do not injure the underlying structures: *thymus gland*; *heart*; *phrenic nerves*; *pericardium* and two separate *pleural cavities*; *lungs*; *diaphragm*; *falciform ligament*; *liver* (5 lobes); *gall bladder*; *œsophagus*; trace the gut commencing with the *stomach*; *pyloric sphincter*; *bile duct*; *duodenum*; *pancreas*; *pancreatic duct*; *portal vein* and *hepatic artery* lying under bile duct in the *duodeno-hepatic mesentery* (*small omentum*); *small intestine*; *sacculus rotundus*; *cæcum*; *vermiform appendix*; *colon*; *rectum*; *kidneys*; *suprarenal bodies*; *bladder*; *oviducts* and *ovaries* in female. (Observe also the *inferior vena cava* and *dorsal aorta*, the *cœliac* and *anterior mesenteric* branches of the latter; also the *sympathetic cœliac ganglia* lying on either side of the last.)

25. Œsophagus and stomach of Sheep: *œsophagus*; *rumen*; *reticulum*; *psalterium*; *abomasum*; *pyloric sphincter*; *duodenum.*

26. Mammary glands and teats: (*a*) *Echidna*, hairless area of skin with modified sweat glands: (*b*) *Anthropoid Ape*, sebaceous gland and true teat: (*c*) sebaceous glands and false teat.

27. (*a*) **Elasmobranchii,** e.g. *Dogfish, Callorhynchus.* Primitive form. Gill pouches opening separately to exterior. Each arch consists of a septum, covered externally by skin and bearing an anterior and posterior gill-lamella, or hemibranch.

(*b*) **Chondrostei,** e.g. *Sturgeon.* Gills covered by an operculum borne by hyoid arch. Septum reduced so that hemibranchs project at outer end into branchial chamber.

(*c*) **Teleostei.** Septum further reduced.

Operculum; *septum*; *anterior* and *posterior hemibranchs*; *branchial arch* and *gill ray* (*cartilaginous*).

External Gills.

(*d*) Larva of *Polypterus.* One pair, in hyoid region.

Larvæ of *Protopterus* and *Lepidosiren.* Four pairs, borne on branchial arches. External gills in adult *Protopterus.*

(*e*) Larvæ of **Urodela** and **Anura.** Also in *Amblystoma.*

(*f*) Adult *Necturus.*

28. Ventral view of the heart and great vessels of the Skate as exposed by the removal of the skin and muscles behind the lower jaws, of the middle portion of the pectoral girdle, and of the ventral wall of the pericardium. Carry the knife inwards for a short distance from each gill-slit: *sinus venosus*; *auricle*; *ventricle*; *conus arteriosus*; *bulbus arteriosus*; *pericardio-peritoneal openings*; *hepatic sinus*; *ductus Cuvieri*; *ventral aorta*; *two afferent branchial vessels*, anterior dividing into two, posterior into three; *gill arches* bearing 9 hemibranchs; *thyroid gland.*

Dorsal arterial system as seen by removing the mucous membrane from the roof of the mouth: *three efferent branchial vessels*; *dorsal aorta*; *subclavian artery*; *cœliac artery*; *vertebral artery*; *common carotid artery*; *external* and *internal carotid arteries*; *gill arches.*

29. View of heart, ventral aorta and gills of the Whiting: *ductus Cuvieri*; *sinus venosus*; *auricle*; *ventricle*; *bulbus arteriosus*; *ventral aorta*; *four branchial arteries*; *gill rakers*; *five branchial clefts*; *gill filaments*; *pseudobranch.*

Dorsal arterial system of the same: cut through angle of mouth and operculum on the right side, and through the middle of each branchial arch: *four efferent branchial arteries*; *right suprabranchial artery*; *subclavian artery*; *cœliac artery*; *dorsal aorta*; *roots of aorta* anastomosing in front in the skull; *anterior* and *posterior external carotids.*

In injected specimens of Cod: *hyoidean vessel* from ventral end of *first efferent branchial* to *pseudobranch*; *ophthalmic artery* from pseudobranch passing round *external carotid* anastomosed to its fellow and passing to the eye.

30. Vascular system of the Newt: observe that the venous system is almost the same as in the Frog: *ventricle*; *right* and *left auricles*; *truncus* (*conus*) *arteriosus*, *first* or *carotid arch*; *external* and *internal carotids*; *carotid gland*; *second* or *systemic arch*; line of pigment showing larval connection of arches 1 and 2 (*ductus Botalli*); *dorsal aorta*; *subclavian artery*; *cœliaco-mesenteric artery*; *third arch*; *fourth* or *pulmonary arch*; connection of the fourth to the second and third arches.

31. Heart and arterial system of the Lizard: *auricles*; *ventricle*; *aortic arches*; *carotid arches* from *right aortic arch*; connection between the carotid and aortic arches (*ductus Botalli*); *pulmonary arteries* and *lungs*; *dorsal aorta*; *subclavian arteries* arising from right aortic arch—that of the left side passes across dorsal to œsophagus; *vertebral arteries*; *cœliaco-mesenteric artery*; *renal arteries*; *genital arteries*; *iliac arteries*; *caudal artery.*

32. The venous system of the Pigeon: *right auricle*; *anterior venæ cavæ* with *pectoral*, *brachial*, *jugular* and *vertebral veins*; *posterior vena cava* with *hepatic*, *epigastric*, *iliac*, *caudal*, *posterior mesenteric* and *coccygeo-mesenteric veins*; *portal vein*; *left auricle* with *pulmonary veins*.

33. The arterial system of the Pigeon: *left ventricle*; *aortic arch*; *innominate*, *common carotid*, *vertebral*, *external* and *internal carotid*, *brachial* and *pectoral arteries*; *dorsal aorta*, with *cœliac*, *anterior mesenteric*, *renal*, *femoral*, *sciatic*, *internal iliac*, *posterior mesenteric* and *caudal arteries*.

34. Vascular system of the Rabbit: remove gut and spleen, cutting through œsophagus, portal vein, bile duct, dorsal mesentery and rectum (cut the arteries close to the gut): turn the heart towards the animal's right side; *left auricle*; *left ventricle*; *left superior vena cava* dividing into *left subclavian* and *external jugular veins*; *left pulmonary veins* and *arteries*; *aortic arch*; *innominate artery* giving off *right subclavian* and both *common carotid arteries*; *left subclavian*; *dorsal aorta* giving off the *cœliac*, *anterior mesenteric*, *renal*, *genital* and *posterior mesenteric arteries* and terminating in the two *common iliac* and the *median sacral arteries.* (The *left phrenic nerve* may be traced to the diaphragm and the two *vagus nerves* seen by the aortic arch.)

35. Ventral view of the urinogenital organs of the Skate: carry the knife forwards from the left abdominal pore into the abdominal cavity and slit open the cloaca; remove the peritoneum, taking care not to injure the ducts, and turn the gut over to the right side:

(*a*) Male: *testis*; *vasa efferentia*; *mesonephric* or *Wolffian duct* functioning as *vas deferens*; *mesonephros*; *vesicula seminalis*; *sperm sac*; *metanephros*; *metanephric duct* or *ureter*; *cloaca*; *anus*; *urinogenital papilla*; *abdominal pores*; *pelvic fin* with *clasper.*

(*b*) Female: *ovary*; *pronephric* or *Müllerian duct* functioning as *oviduct*; *internal opening of oviduct*; *shell gland*; *cloacal opening of oviduct*; *mesonephros*; *metanephros*; *ureter*; *cloaca*; *anus*; *urinary papilla*; *abdominal pores*; *pelvic fins.*

36. Ventral view of the urinogenital organs of the Newt:

(*a*) Male: *testis*; *fat body*; *vasa efferentia*; *longitudinal duct of same*; *mesonephros*; *Wolffian* or *mesonephric duct*; remains of the *Müllerian* or *pronephric duct*; *metanephros*; *metanephric duct* (*ureter*); *rectum*; *cloaca.*

(*b*) Female: *ovary*; *Müllerian duct* or *oviduct*; remains of *vasa efferentia* and *longitudinal duct* of male; *mesonephros*; *metanephros*; *Wolffian duct* joined by the *metanephric ducts* (*ureters*); *rectum*; *cloaca.*
Transverse section of metanephros of Newt showing a *nephrostome.* (Demonstration specimen.)

37. Ventral view of the urinogenital organs of the Snake:

(*a*) Male: *testis*; *epididymis* (remains of *mesonephros*); *vas deferens* or *Wolffian duct*; *lobulated metanephros*; *ureter* or *metanephric duct*; *rectum*; *bladder*; *cloaca*; *urinogenital papillæ*; *penes.*

(*b*) Female: *ovary*; *oviduct* or *Müllerian duct*; *lobulated metanephros*; *ureter* or *metanephric duct*; *bladder*; *cloaca.*

38. Ventral view of the urinogenital organs of the Pigeon: *metanephros* or *kidney*; *suprarenal bodies*; *ureters*: *testes* or *ovary*; *vasa deferentia* (*Wolffian ducts*) or *oviduct* (*Müllerian duct*) with its wide *internal opening*; *rectum*; *cloaca*; *bursa Fabricii.*

39. Ventral view of the urinogenital organs of the Rabbit: the viscera should have been removed, and the pubis divided and removed on one side: *kidneys*; *suprarenal bodies*; *ureters*; *bladder*; (*a*) in male: *testis* pulled out of *scrotal sac*; *epididymis*; *vas deferens*; *uterus masculinus*; *prostate gland*; *urethra*; *perineal glands*; *genital cord*; (*b*) in female: *ovaries*; *oviducts*; *uteri*; *vagina*; *vestibule*; *perineal glands*; *genital cord.*

40. Cloaca and female genital organs of Echidna: *ovary*; *internal opening of oviduct*; *oviduct*; *uterus*; *urinogenital sinus*; *bladder*; *ureters*; *rectum*; *cloaca*; *cloacal sphincter*.

41. Cloaca and male generative organs of Kangaroo: *testis*; *epididymis*; *vas deferens*; *kidney*; *ureter*; *bladder*; *urinogenital sinus*; *retractor penis*; *rectum*; very shallow *cloaca.*

Cloaca and female generative organs of Kangaroo: *ovary*; *internal opening of oviduct*; *oviduct*; *uterus*; *lateral vagina*; *fused median vaginæ*; *urinogenital sinus*; *opening of bladder*; *rectum*; *cloaca*; *cloacal sphincter.*

42. Dorsal view of the brain and cranial nerves of the Skate: *olfactory lobes*; *cerebrum*; *thalamencephalon*; *optic lobes*; *cerebellum*; *medulla oblongata*; *restiform body*; *spinal cord*; *optic nerve* (II); *motor oculi* (III), with branches to *recti internus*, *superior*, *inferior* and *obliquus inferior*; *patheticus* (IV) to *obliquus superior*; *trigeminal* (V) with its *rami profundus*, *maxillaris* with *palato-nasal branch* and *mandibularis*; *abducens* (VI) to *rectus externus*; *facial* (VII) with its *ophthalmicus superficialis*, *palatine*, *hyomandibular* and *chorda tympani branches*; *auditory* (VIII); *glossopharyngeal* (IX) across floor of auditory capsule dividing to the hyoid and 1st branchial arches; *vagus* (X) along anterior cardinal sinus breaking up into *four branchial*, *lateral line* and *visceral* branches.

43. Ventral view of brain of Skate: *olfactory lobes*; *cerebrum*; *optic chiasma* and *nerves*; *infundibulum*; *pituitary body*; *crura cerebri*; *medulla oblongata*; *restiform tracts*; *roots of cranial nerves III*, *V*, *VI*, *VII*, *VIII*, *IX*, and *X*.

44. Dorsal view of brain and cranial nerves of Whiting; before opening the cranium, strip off the skin and trace the *cutaneous branches of V* over the body; at the same time observe the branches of X along the sides of the body: *olfactory lobes*; *cerebrum*; *optic lobes*; *cerebellum*; *medulla oblongata*; *spinal cord.*

Dissect out the nerves and observe that they are essentially the same as in the Skate but the *ramus superficialis of V* replaces the *ramus profundus.* Note the *auditory organ* with its large *otolith.*

45. Brain and cranial nerves of Frog as seen from above: *olfactory lobes*; *cerebral hemispheres*; *thalamencephalon*; *optic lobes*; *cerebellum*; *medulla oblongata*; *fourth ventricle*; *spinal cord*; *optic nerve* (II); *trigeminal nerve* (V) with *Gasserian ganglion*, and *ophthalmic*, *maxillary* and *mandibular branches*; connection of sympathetic chain of ganglia with Gasserian ganglion; *palatine nerve* (VII) with *palatine* and *hyomandibular branches*; *glossopharyngeal nerve* (IX); *vagus nerve* (X) with *vagus ganglion*; *hypoglossal* or 1*st spinal nerve.*

46. Dorsal view of central nervous system of Pigeon: *olfactory lobes*; *cerebral hemispheres*; *pineal body*; *optic lobes*; *cerebellum*; *medulla oblongata*; *spinal cord*; *spinal nerves to fore limbs*; *sinus rhomboidalis* and *nerves to hind limbs.*

47. Dorsal view of brain of Rabbit removed from the skull; one *cerebral hemisphere* is to be pulled out outwards to display the *corpus callosum* (connecting the two hemispheres) and the *thalamencephalon* with its thickened wall, the *optic thalamus.* Note also the *pineal body* on roof of thalamencephalon; *optic lobes* (*corpora quadrigemina*); *median* and *lateral lobes of cerebellum*; *cranial nerve IV* (between optic lobes and cerebellum); *medulla oblongata* with *restiform body*; *roof of ventricle IV*; *dorsal fissure of spinal cord.*

Ventral view of same: *olfactory lobes*; *temporal lobes*; *optic chiasma* and *nerves*; *Sylvian fissure*; *infundibulum*; *pituitary body*; *crura cerebri*; *pons Varolii*; *medulla oblongata*; *III, V—XII roots of cranial nerves.*

48. Fish. Scales. (1) *Placoid* (Dogfish).
(2) *Ganoid* (*Amia* and *Polypterus*).
(3) *Cycloid* (Whiting).
(4) *Ctenoid* (Perch).
(5) *Clupeoid* (Herring).

Observe that the Sturgeon has bony plates covering the head and extending down the body in five rows.

49. Reptiles. (1) Horny epidermal scales of Lizards and Snakes, on the ventral side of the latter commonly forming great ventral shields beneath which the ribs end.

(2) Horny epidermal plates of Tortoises, which over the body cover the bony carapace and plastron.

(3) Horny scales and bony plates in the Crocodile.

5c. Birds. Feathers. (1) Quill feather: *quill*; *shaft*; *vane* formed of *barbs*; *superior* and *inferior umbilicus*. Mount on a slide a portion of the vane, after soaking in 90 per cent. alcohol: *barbules*; *hooklets*.

(2) Down feathers.

(3) Filoplume with *rudimentary vane*.

Observe the cornified skin of the feet (often scaly), beak and claws of all birds.

Note the resemblance of the small feathers of the Penguin's wing to scales.

51. Mammals. (1) Cornifications in claws (Unguiculata), nails (Primates) and hoofs (Ungulata).

(2) Contour and woolly hairs; bristles; quills of *Echidna*, Hedgehog and Porcupine.

(3) Fusion of hairs to form the horns of the Rhinoceros and the baleen of Whales.

(4) The scales of the Armadillo covering bony plates in the dermis and the overlapping scales of the Pangolin.

(5) The beak of *Ornithorhynchus*.

(6) The horns of the Ox and Antelope supported by bony cores on the frontal bones.

52. Vertebræ of Rabbit.

Second lumbar vertebra: (*a*) front view: *anterior epiphysis* covering *centrum*; *neural arch*; *neurapophysis*; *metapophysis*; *transverse process*; *prezygapophysis*; *hypapophysis*: (*b*) side view: *centrum*; *postzygapophysis*; *anapophysis*; *anterior epiphysis*; *intervertebral notch* (for exit of spinal nerve). Other names as in (*a*).

Atlas (first cervical) vertebra, front view: *transverse process*; *prezygapophysis.*

Axis (second cervical) vertebra, side view: *odontoid process*; *neurapophysis.*

Third cervical vertebra, front view: *foramen for vertebral artery.*

Third dorsal vertebra, side view: *neurapophysis*; *facet for tubercle of rib*; *facet for head of rib.*

Sacrum, ventral view: *surface of fusion with ilium.*

53. The vertebral column:

(*a*) Absent, notochord in sheath: Amphioxus.

(*b*) Unconstricted notochord with vertebræ formed by more or less perfect neural and hæmal arches: Cyclostomata, Holocephali, Chondrostei and Dipnoi.

(*c*) Constricted notochord, persisting (i) through biconcave cartilaginous vertebræ: Selachii; or (ii) through biconcave bony vertebræ: Gymnophiona and lower Urodela.

(*d*) Pads of notochord occupying the intercentral spaces between biconcave bony vertebræ (*amphicœlous*): Teleostei, Crossopterygii, and some Reptiles (*Sphenodon*, Geckonidæ, etc.).

(*e*) Notochord obliterated and well formed bony vertebræ differentiated into types by the character of the surfaces by which the *centra* articulate with one another:

(i) *Procœlous*, hollow in front, a knob behind: most Anura, many Reptiles.

(ii) *Opisthocœlous*, a knob in front, hollow behind: Holostei, higher Urodela, many Reptiles.

(iii) *Heterocœlous*, saddle-shaped articulations: Birds.

(iv) *Amphiplatyan*, flat at each end with epiphyses between: most Mammals.

54. Pectoral girdle and fin of Dogfish, side view: *primary cartilaginous pectoral arch*; *fin* supported by three cartilaginous *basalia*, many cartilaginous *radialia*, and distally numerous horny *fin-rays.*

55. Pectoral girdle and fin of Cod, side view: reduced cartilaginous arch represented by two bones, *scapula* (dorsal) and *coracoid* (ventral); *large secondary arch* (*clavicle*) formed of four membrane bones; *fin* supported by *four brachial ossicles* (*basalia-radialia*) and numerous *dermal bony fin-rays.*

56. Pectoral fin of *Ceratodus*: *central segmented axis* carrying *radialia* on either side.

57. Pectoral girdle of Frog, ventral view: *primary arch* consisting of the *suprascapula*, *scapula* and *coracoid* (partly ossified with a large fenestra, the parts in front and behind which are often termed "coracoid" and "precoracoid"); *glenoid cavity*; *secondary arch* represented by the *clavicle* (fused to the "precoracoid"); functional "sternum" fused in front (*omosternum*) and behind (*sternum*) to the pectoral girdle.

58. Pectoral girdle of Toad, ventral view: *overlapping coracoid plates*; "*sternum.*"

59. Pectoral girdle and limb of Lizard, ventral and side views: *suprascapula*; *scapula*; fenestrated *coracoid* (partly ossified); *clavicle*; *interclavicle*; broad *sternum*; *humerus*; *radius* and *ulna*; *wrist* (*carpus*); *digits.*

In the Museum examine other forms of Reptiles to see the considerable modifications found in the Group.

60. Pectoral girdle and limb of Fowl, side view: *scapula*; *coracoid*; *clavicle*; enlarged *sternum* with *keel* for attachment of muscles for flight; *humerus*; *radius* and *ulna*; *carpus*; *digits* 1—3.

Examine the same parts in the Penguin where the limbs are swimming organs, and in Ratite birds.

61. Pectoral girdle and limb of Rabbit, side view: *scapula* with *spine*, *acromion* and *coracoid process*; *humerus*; *radius* and *ulna*; *carpus*; *digits*.

In the pectoral girdle of Monotremata notice the *interclavicle*, *coracoid* and *precoracoid* (Reptilian features).

62. Human manus showing the bones of the wrist and fingers: *radiale* (*scaphoid*) to which the *centrale* has fused; *intermedium* (*lunar*); *ulnare* (*cuneiform*); *carpale* 1 (*trapezium*); *carpale* 2 (*trapezoid*); *carpale* 3 (*magnum*); *fused carpale* 4 *and* 5 (*unciform*); *metacarpals*; *digits*.

63. In the Museum examine the carpus of various forms (Whale, Horse, Cow, Elephant, Bat, etc.) to see the range of modification.

64. Pelvic girdle and fins of Dogfish, ventral view: *single cartilaginous pelvic bar*; fin supported by *one basal cartilage*, many *radialia* and numerous *horny fin-rays*. (In the male note the *claspers*.)

65. Pelvic fins of Cod, ventral view: *there is no pelvic girdle*: fins supported by *one large basal piece* on either side and consisting of a few *dermal bony fin-rays*.

66. Pelvic girdle and limb of Frog: elongated *ilium* (an adaptation to jumping); *ischium*; *pubis*; *acetabulum*; *femur*; *tibio-fibula*; *proximal tarsals* consisting of the elongated *tibiale* (*astragalus*) and *fibulare* (*calcaneum*); *three distal tarsals*; *five metatarsals*; *five main digits* and supplemental digit, the *prehallux* (*calcar*).

67. Pelvic girdle and limb of Lizard: *ilium*; *ischium*; *pubis*; *femur*; *tibia* and *fibula*; *two rows of tarsals*; *five metatarsals*; *five digits.*

In the Museum examine other forms of Reptiles to see the considerable modification found in the Group.

68. Pelvic girdle and limb of Fowl: observe the number of vertebræ fused to form the large *synsacrum*: *ilium*; *ischium*; *pubis*; *acetabulum*; *femur*; *tibia*, and *fibula* with which the proximal row of the *tarsus* has fused; *tarsometatarsus* formed by the fusion of the *distal tarsals* and the *metatarsals*; *four digits*.

Pelvic girdle of Ostrich: observe the symphysis of the posterior portion.

69. Pelvic girdle and limb of Rabbit: *ilium*; *ischium*; *pubis*; *acetabulum*; *femur*; *tibia* and *fibula*; *tibiale* and *fibulare*; *centrale*; *three distal tarsals*; *four metatarsals*; *four digits.*

70. Human pes showing the bones of the ankle and toes: fused *tibiale* and *intermedium* (*astragalus*); *fibulare* (*calcaneum*); *centrale* (*navicular*); *tarsale* 1 (*entocuneiform*); *tarsale* 2 (*mesocuneiform*); *tarsale* 3 (*ectocuneiform*); *fused tarsale* 4 *and* 5 (*cuboid*); *five metatarsals*; *five digits.*

71. In the Museum examine the tarsus of various forms to see the range of modification.

72. Skull and visceral skeleton of Dogfish, side view: *nasal capsule*; *orbital region*; *auditory capsule*; *occipital region*; *palato-pterygo-quadrate bar* (upper jaw); *Meckel's cartilage* (lower jaw); *hyomandibula* with *ceratohyal* and *basihyal*; *five segmented branchial arches.* (The jaws are supported by the hyomandibula, i.e. the suspension is *hyostylic.*)

73. Skull and visceral skeleton of *Chimæra* for comparison with last: *palato-pterygo-quadrate bar* fused to the *chondrocranium* (cartilaginous cranium); *branchial arches* more compressed. (The jaws are directly attached to the skull, i.e. the suspension is *autostylic*, cf. Dipnoi, Amphibia and all higher forms.)

74. Skull of *Amia*: (*a*) dorsal view: *premaxilla*; *mesethmoid*; *nasal*; *adnasal*; *lacrymal*; *maxilla*; *suborbitals* (2); *prefrontal*; *frontal*; *postfrontal*; *dorsal* and *ventral postorbitals*; *parietal*; *pterotic*; *supratemporal*; *post-temporal*; *preoperculum*; *operculum*.

(*b*) Ventral view: *premaxilla*; *maxilla*; *vomer*; *palatines* (2); *pterygoid* (three bones, viz. *entopterygoid*, *ectopterygoid*, *metapterygoid*); *quadrate* with articular surface; *parasphenoid*; *basioccipital*; *post-temporal*; *pro-otic*; *opisthotic*; *hyomandibula*; *symplectic* with articular surface.

(*c*) Side view of hyoid arch and lower jaw: *hyoid arch* consisting of *hyomandibula* and *symplectic* (partly covered by *preoperculum*, *operculum*, *suboperculum*, and *interoperculum*) continuing below as *epihyal*, *ceratohyal* and *hypohyal*: lower jaw consisting of dentary (covering *Meckel's cartilage*), *articular*, *angular* and *supra-angular* bones.

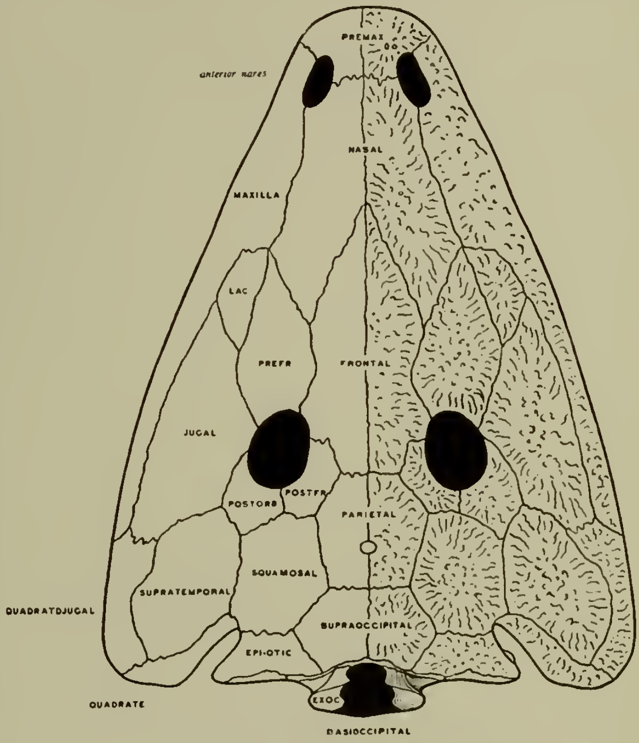
75. Skulls of Cod (bony), Sturgeon (cartilage with some bones) and Salmon (equal proportions of bone and cartilage) for comparison with *Amia.*

76. Skull of Frog, investing bones removed on one side: (*a*) dorsal view: *premaxilla*; *maxilla*; *nasal*; *sphenethmoid*; *fronto-parietal*; *pro-otic*; *pterygoid*; *squamosal*; *quadratojugal*; *exoccipital*: (*b*) ventral view: *premaxilla*; *maxilla*; *vomer*; *parasphenoid*; *palatine*; *sphenethmoid*; *pterygoid*; *quadratojugal*; *pro-otic*; *exoccipital*.

77. Skulls of Urodela: note the absence of *quadratojugals*, *sphenethmoid* and of any definite tympanic cavity: the *palatine* is parallel to the axis of the cranium, and a *large parasphenoid* is present.

(Compare with the skull of *Capitosaurus* on the next page. The skulls of living Amphibia may be regarded as simplified forms of this type.)

78. These may be derived from the Stegocephalian type (*Capitosaurus*), which is completely armoured, by the formation of spaces or *vacuities* between the sutures of certain bones chiefly in the hinder, upper and lateral surfaces of the skull. The bones forming the bridges between these are known as the *arcades*.



Skull of *Capitosaurus*, dorsal view.

There are four main types found in the Reptilia. Type I is shown by the extinct Ichthyosauria, Plesiosauria and Anomodontia (from the latter group Mammals are supposed to be derived) and with a slight modification in such *Chelonia* as the tortoises (*Emys*, etc.). [N.B.—The ordinary turtle, *Chelone*, is still more modified by the expansion of the *frontals* and *parietals* as plates covering the large temporal muscles; *Emys*, or some similar form, therefore should be studied as an example]. In this type there is a *single broad arcade* along the "cheek," formed by the *supratemporal*, *squamosal*, *quadratojugal* and *postfrontal* bones. Above this is the single large *supratemporal vacuity*.

By the formation of a second vacuity in the arcade of the first type type II is obtained. It is shown by the extinct Dinosauria and Pterodactyla, the primitive living Rhynchocephalia (*Sphenodon*) and by the Crocodilia. There is now a *lower arcade*, i.e. the lower part of the arcade of type I, formed by *quadrate*, *quadratojugal* and *jugal*, which joins a process from the *postfrontal* and *maxilla*; above this is the *lower lateral temporal vacuity*. The upper arcade, i.e. the upper part of type I, is formed by joining processes of the *squamosal* and *postfrontal* which separate the *upper* and *lower lateral temporal vacuities*. Type II shows the largest number of arcades, the remaining types showing a loss of one or of both arcades—designed to give greater freedom of movement to the *quadrate* and consequently a greater power of expansion of the lower jaw.

Type III, shown in the *Lacertilia*, is produced from type II by the loss of the *quadratojugal* and the consequent rupture of the lower arcade.

Type IV, shown in the *Ophidia*, is produced by the loss of the *quadratojugal* and the joining processes of the *postfrontal* and *squamosal* so that there are no arcades left.

Birds can be derived from type II by the retention of the lower and loss of the upper arcade.

79. Skull of Lizard (*Uromastix*): (*a*) dorsal view: *premaxilla*; *maxilla*; *nasal*; *lacrymal*; *frontals* (fused); *pineal foramen*; *parietals* (fused); *supraoccipital*; *condyle*; *postfrontal*; *jugal*; *squamosal*; *upper lateral temporal vacuity*; (*transpalatine*, *palatine*, and *pterygoid* seen below *orbit*).

(*b*) Ventral view: *premaxilla*; *maxilla*; *vomer*; *palatine*; *pterygoid*; *transpalatine* (*ectopterygoid*); *jugal*; *quadrate*; *parasphenoid*; *basisphenoid*; *basioccipital*; *exoccipital*; *pro-otic.*

(*c*) Lateral view: *premaxilla*; *maxilla*; *nasal*; *lacrymal*; *jugal*; *squamosal*; *quadrate*; *supratemporal*; *upper lateral temporal vacuity*; *pterygoid*; *transpalatine*; *columella cranii* (*epipterygoid*); *pro-otic*; sides of *nasal*, *frontal* and *parietal.*

(*d*) Hind view: *parietal*; *supraoccipital*; *exoccipital*; *basioccipital*; *quadrate*; *squamosal*; *posterior temporal vacuity.*

Lower jaw: inside view: *dentary*; *Meckel's cartilage*; *angular*; *splenial*; *articular*; *supra-angular*; *coronoid.*

80. Skull of *Sphenodon*, lateral and hind views; note the *upper temporal arcade* formed by the *post-frontal* and *squamosal*, and the *lower arcade* formed by the *jugal*, *quadratojugal* and *quadrate*; *posterior temporal* and *upper* and *lower lateral temporal vacuities*.

81. Skull of Tortoise: note the *single broad arcade* and *upper lateral vacuity*.

82. Skull of Snake: compare with Lizard and note *long cranial cavity* extending into the orbital region; *absence of arcades* and of the *epipterygoid*; fused *premaxillæ*, very small and only united to *maxillæ* by ligaments; *squamosal* and *quadrate* elongated and movable to allow of great expansion of lower jaw; *rami of lower jaw* only connected at symphysis by ligament.

83. Skull of Fowl, lateral view: note thinness of bones and obliteration of sutures: single *condyle*; beak formed by the *premaxilla*; reduced *maxilla*; large *nasal*; *lacrymal*; thin rod-like *jugal* and *quadratojugal*; large *quadrate*; *mesethmoid*; *cartilaginous interorbital septum*; *palatine*; *pterygoid*; *tympanic cavity*; *squamosal*; *alisphenoid*.

(In the ventral view observe that the *parasphenoid* is represented by the large *basitemporal*, underlying most of the *basisphenoid* and part of the *basioccipital*, and by a *bony rostrum* extending forwards from the *basisphenoid*. The *lower jaw* contains the same elements as in Reptiles.)

84. Skull of Dog as a type of the Mammalia: (*a*) dorsal view: *premaxilla*; *nasal*; *frontal*; *parietal*; *supraoccipital*; *maxilla*; *lacrymal*; *jugal*; *squamosal.*

(*b*) Side view, zygomatic arch partly cut away: *premaxilla*; *maxilla*; *lacrymal*; *jugal*; *squamosal*; *palatine*; *pterygoid*; *tympanic bulla*; *exoccipital* with *condyle*; *nasal*; *frontal*; *parietal*; *supraoccipital*; *alisphenoid*; *orbitosphenoid*; *incisor*, *canine*, *premolar* and *molar teeth.*

Foramina: *infraorbital* (exit from orbit of branch 2 of nerve V); *lacrymal*; *optic* in orbitosphenoid; *lacerum anterius* (nerves III, IV, VI and branch 1 of V) in the boundary between orbitosphenoid and alisphenoid; *rotundum* (branch 2 of nerve V) in alisphenoid; *ovale* (branch 3 of nerve V) in alisphenoid, obscured by a bridge of bone forming *alisphenoid canal* containing a branch of internal carotid artery; *external auditory meatus.*

84 (*continued*). (*c*) Ventral view: *premaxilla*; *maxilla* with *palatine plate*; *palatines*; (*vomers* and *mesethmoid* covered by foregoing but identified together with the *turbinals* by looking down the *anterior narial opening*); *pterygoid*; *presphenoid*; *basisphenoid*; *basioccipital*; *alisphenoid*; *jugal*; *squamosal* with *glenoid surface*; *tympanic bulla*; *exoccipital* with *condyle.*

Foramina: *anterior* and *posterior* (2) *palatine*; *postglenoid* (vein); *lacerum medium* (*artery*); *eustachian*; *stylomastoid* (nerve VII); *lacerum posterius* (nerves IX, X, XI); *condylar* (nerve XII); other foramina as in side view.

85. Differentiation of Teeth: (*a*) *homodont*, one kind, single cusps and roots (Shark, Lizard, Crocodile, etc.); (*b*) *heterodont*, different kinds such as incisors, canines, premolars and molars, often several cusps and roots (most Mammals, cp. Dog); (*c*) *secondarily homodont* (toothed Cetacea).

86. Implantation of Teeth: (*a*) loose in skin of jaws (Sharks); (*b*) *acrodont*, fused to the top of the jaw (Snakes, *Sphenodon* and some Lizards); (*c*) *pleurodont*, fused to the inner side of the jaw (Frog and some Lizards); (*d*) *thecodont*, loosely implanted in sockets (Crocodiles and all Mammals).

87. Crown pattern of Teeth: (*a*) *conodont*, single cusp (Crocodile or Mammalian canines or incisors); (*b*) *triconodont*, three cusps in one plane (a few extinct Mammals); (*c*) *tritubercular*, three cusps in a triangle (most early fossil Mammals, some teeth of Insectivora, Marsupialia, Lemuroidea, etc.); (*d*) *bunodont*, broad crown with blunt or pointed cusps; (*e*) *lophodont*, broad crown with cusps joined by transverse ridges (Tapir, Rhinoceros, etc.); (*f*) *Selenodont*, broad crown with cusps spread out in form of crescentic ridges (Ox, Sheep, etc.).

Hypsodont teeth are similar to the last with high crowns, rising in their sockets as their surfaces wear down (Ox, etc.) and *brachydont* teeth are low crowned teeth (Pig, etc.).

88. Skulls and teeth of different orders of Mammals. Make drawings and notes where necessary.

Note. The following characters are *primitive* for the mammalian skull generally, being found widely spread among the earlier extinct forms as well as among the smaller and more primitive recent forms, both of Marsupials and Placentals:—

1. Small size, short face with terminal nares. (Note secondary elongation of muzzle in certain Insectivores.)
2. Low rounded brain case constricted in the frontal region, indicating a small and primitive brain.
3. Optic and temporal fossæ confluent.
4. Lacrymal bone not confined to the orbit but extending over the face. The foramen outside or on the rim of the orbit.
5. Tympanic ring-shaped, not forming a bulla.
6. Posterior end of palate thickened (common among Marsupials but also occurs in Insectivores).
7. Lateral foramina at hind end of the palate which transmit blood vessels to the roof of the mouth (common among Marsupials, certain Insectivores and Rodents).
8. Large exposure of the mastoid in the occipital region.
9. Optic foramen and foramen lacerum anterius confluent.
10. Weak symphysis of the halves of the lower jaw.

Among Placentals the Insectivora have the greater number of these primitive features. Every living mammal, however, is a compound in varying degree of these primitive characters, together with some which are adaptive.

Adaptive characters are those which show special modification for some particular function, e.g. securing and eating of specialised kinds of foods, fighting or defence, etc. The dentition shows the results of this adaptation very clearly. Owing to similar methods of feeding it will often be found that animals of one group tend to resemble those of some other group in their dentition. [e.g. the secondary homodont dentition of the Cetacea is reptilian-like. The Marsupials also have different types of dentition which "mimics" that of the Rodents, Ungulates and Carnivores, etc.]

Notice also the effect that different methods of chewing the food have on the shape of the condyles of the lower jaw which may be round, transverse or elongated.

Modifications due to such characters as enlarged incisor teeth, the presence of horns, the angle which the face makes with the cranium, etc., should be noted.

The following characters may be regarded as *adaptive*:—

1. Specialised grinding, gnawing, carnivorous, fruit- and fish-eating dentitions; any great reduction or absence of teeth.
2. Any great elongation or abbreviation of the skull.
3. Enlargement of the brain case either in the walls of the skull (e.g. elephant) or in the skull capacity itself (e.g. Primates). This enlargement of brain capacity is very noticeable when the early fossil and recent forms of any order are compared.
4. Separation of orbital and temporal fossæ (cp. Primates).
5. Secondary loss of bones (e.g. loss of jugal, shortening of nasals).
6. Closure and obliteration of sutures.
7. All sculptured markings; excess of bone; horns, etc.

Primitive characters are a test of affinity while adaptive characters may be very misleading in this respect.

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7